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Abstract
This paper evaluates the macroeconomic effects of macroprudential policy measures consisting of changes in loan-to-value ratios in the euro area. The analysis is carried out within a fully structural, multi-country model, that prominently includes financial frictions and a banking sector. Our main findings suggest that a permanent LTV tightening in a small euro area economy leads to a long-run decline in lending to the private sector. The short-run impact depends crucially on the policy design, being less pronounced when the measure is phased-in. This is consistent with policy goals of curbing credit growth but avoiding an abrupt immediate contraction in lending. A policy measure introduced at the euro area level implies larger long-run effects but the short-run recessionary impact is attenuated by the monetary policy response.

JEL: E58, E61, F42

Keywords: Macroprudential policy, loan-to-value ratio, financial frictions.

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1. Introduction

Recessions associated with credit and house prices busts tend to be longer and usually are more severe than typical recessions (Claessens *et al.* (2008)). The awareness of the deep impact of housing busts, especially after the global financial crisis (GFC), led macroprudential policymakers to take preemptive actions to mitigate the occurrence of busts and to build banking system and private sector resilience. Borrower-based measures, such as limits to loan-to-value (LTV), debt-service-to-income (DSTI) and loan-to-income (LTI) ratios on residential lending have been applied in several countries (IMF (2011)), including in Europe (ESRB (2017)). In the majority of the cases, these policy measures are permanent, only in a few cases are temporary (e.g. New Zealand). Given the increased used of macroprudential measures, the study of their real effects and understanding of how these may hinge on the implementation design are crucial issues for policymakers.

Building on the work of Kiyotaki and Moore (1997) and Iacoviello (2005), a recent stream of dynamic stochastic general equilibrium (DSGE) models with collateral constraints and mortgage lending highlight the role of countercyclical LTV ratios to counteract financial imbalances related to credit and developments in the real estate sector. In this strand of the literature, the LTV ratio is a policy variable that follows a rule that feedbacks countercyclically on financial and macroeconomic variables, in the spirit of a Taylor rule. Policies based on countercyclical LTV ratios are shown to be beneficial in stabilizing the economy and in increasing welfare (see Rubio and Carrasco-Gallego (2016), Quint and Rabanal (2014) and Brzoza-Brzezina *et al.* (2015) for euro area applications).

The literature addressing the effects for the business and financial cycles of permanent tightenings of LTV ratios is scarcer. Lambertini *et al.* (2013) find that, in a closed economy DSGE model with news-driven cycles, the countercyclical use of a LTV ratio responding to credit is welfare-improving compared to a constant LTV limit. Gambacorta and Signoretti (2014) show that leaning-against-the-wind monetary policies have larger benefits in terms of macroeconomic volatility in an economy with higher LTV ratio but do not model macroprudential policy. None of these papers look at the type of policy measures we analyse in our paper.

Directly related to our work is Robinson and Yao (2016) who focus on the implications of temporary and permanent LTV ratio policies in an estimated closed economy DSGE model for the US with collateral constraints based on housing, heterogeneous households and long-term debt. They find that a permanent reduction of the LTV ratio reduces the depth of recessions and extends expansions, with more visible results for the financial cycles than for the real cycles. Unlike this paper, we work with an euro area open economy model and we focus on the adjustment to permanent and transitory changes of the LTV limit. Our paper contributes to the literature by focusing on crucial

policy questions: (i) we assess the macroeconomic impact of permanent and temporary changes in the LTV ratio in a small economy within a monetary union based on a fully structural model that allows us to illustrate the transmission mechanisms; and (ii) we consider the impact of different policy designs, namely in terms of the speed of implementation. Even though LTV limits have often been implemented as part of a pack of measures (such as in the recent case of Portugal), we focus on the analysis of stand-alone LTV measures and not of combined measures.

Our main findings are as follows. A permanent reduction of the LTV limit of impatient households in a small euro area economy leads to: i) a long-run decline in bank lending to the private sector; ii) a relatively small long-run contractionary macroeconomic impact; and iii) a tightening of borrowing and economic activity in the short run which is less pronounced if the authorities phase-in the tightening of the LTV ratio. If the reduction in LTV ratios is observed across the euro area the long-run macroeconomic impact in each of the regions is larger but in the short run the recessionary impact is mitigated by the monetary policy response.

These findings are relevant to guide policy. A permanent tightening of the LTV ratio leads to a long-run decline in bank lending to the private sector and this can be achieved more or less rapidly, depending on the design of policy implementation. A quicker implementation comes at the cost of a stronger contraction of lending and economic activity in the short to medium run which may have important implications for the successful implementation of the policy measure. Our results lend support to the often announced objective for a gradual implementation, i.e. preventing unintended lending contraction at the time of implementation.

The remainder of the paper is organized as follows. Section 2 reviews the international experience with borrower-based macroprudential policies. Section 3 surveys the empirical literature on the impact of these measures. Section 4 overviews the model and the calibration. Section 5 analyses the simulations. Section 6 discusses policy implications and concludes.

2. International loan-to-value policy experience

Since the GFC (but not exclusively) several countries have implemented borrower-based measures with the aim of mitigating risks stemming from the real estate sector. The introduction of LTV limits has been mostly implemented to contain the excessive growth of credit and house prices. International experience also shows that LTV caps are usually combined with other measures, such as upper limits to LTI and DSTI ratios, and original maturity of loans, the latter usually as a way to prevent circumventing DSTI limits. The aim for combining multiple macroprudential tools of this kind is to assure that the policy intervention is effective by tackling a risk from different perspectives

(Lim *et al.* (2011)). Furthermore, Lim *et al.* (2011) report that macroprudential instruments such as caps on the LTV are set together with other macroeconomic policies, as monetary and fiscal policies (for example, in Asian and American countries).

In the next subsection we survey the use of macroprudential policy measures over the latest years, with particular focus on European countries. Then we overview the empirical evidence on the effectiveness of these measures.

2.1. Overview of policy measures

Based on data collected by the International Monetary Fund for 65 countries, Claessens (2015) concludes that the majority of countries (42) have implemented at least one instrument once during the period from 2000 to 2013 (28 emerging and developing economies and 14 advanced economies). The policy measures used the most were LTV ratios followed by DTI ratios.

Jacome and Mitra (2015) survey the experience of six countries, in particular Brazil, Korea, Hong Kong, Malaysia, Poland, and Romania. These six countries adopted limits on LTV and DTI ratios to mitigate sector specific credit booms. In the majority of cases, the stated objective was to stem excessive credit growth and prevent house price booms. However, the prevailing growth of (sectoral) credit when countries started to tighten the LTV/DTI ratios limits varied significantly. The limits on LTV and DTI ratios were most frequent for mortgages, but in some countries also covered commercial real estate, auto loans, and consumer credit. In most cases, the caps on LTV and DTI for mortgage loans started in the range of 60% to 85% and 30% to 45%, respectively, and were subsequently tightened or differentiated by type of borrower. Limits on commercial properties loans were set at lower levels.

In Europe, the real estate lending has been high on the macroprudential policy agenda over the last years, with caps on LTV, DSTI and LTI ratios commonly used. In 2016, the Czech Republic recommended tightened LTV ratios for mortgage lending, in Norway new regulation included a tightening of LTI and LTV caps, in Slovakia a binding decree was adopted replacing, and in some cases tightening, an earlier non-binding recommendation on limits for housing loans and included a LTV limit and a DSTI limit, and Slovenia issued a recommendation with immediate effect combining LTV and DSTI limits for new housing loans.

In 2017, several other countries applied or reinforced borrower-based measures. This was the case of Denmark, where restrictions were introduced on risky mortgage loans for home owners from 2018 onwards. Iceland introduced a binding LTV limit of 85% (90% for first time buyers) for new mortgage loans starting in July 2017. Norway approved a new regulation, including a LTV cap at 85%, and a new cap at 60% for secondary homes in Oslo. By 2017, around two-thirds of the European Union Member States had a residential real estate related macroprudential measure in place.

In 2018, limits to credit standards were introduced or further tightened in Portugal, Czech Republic, Finland, Slovakia and Hungary.[1] In Portugal, a recommendation was issued introducing, from July 2018 onwards, permanent LTV, DSTI and maturity limits on new lending for consumers, including mortgage agreements and consumer credit agreements, with the aim of promoting the adoption of prudent credit standards on loans granted by the Portuguese financial system to consumers, in order to enhance the resilience of the financial sector and the sustainability of households' financing. In the remaining countries credit standards limits were further tightened or amended.

With respect to European Union countries that have adopted LTV limits, the majority has opted for the application of limits within the range of 85% to 90% (e.g. Slovakia, Slovenia, Finland, Ireland, Latvia, Lithuania, Poland, Norway, Check Republic, and Sweden). It has been also common standard for authorities to further tighten the LTV limits after conducting an impact assessment of the measures.

There are also differences regarding the pace of implementation of the measures. It is more usual to introduce limits in a discrete but permanent manner, though a number of countries have chosen to phase in limits on borrower-based measures. This was the case in Slovakia, the Netherlands, Poland and Czech Republic. The main reason justifying the option for the phasing-in of the measures is to prevent negative impacts on lending. Not only the pace of adjustment differs from country to country (i.e. Poland has opted to decrease the LTV ratio from its initial level by 5 p.p. along 3 years, whereas the Netherlands preferred to reduce it at a pace of 1 p.p. a year from 2012 to 2018), but also the way countries conceive the phase-in of the measures can also be different (e.g. in Slovakia the macroprudential authority has opted to introduce exemptions from the LTV limit, which were reduced each nine months).

To better illustrate the different solutions that were designed by macroprudential authorities regarding the phase-in of policy measures, we choose the aforementioned European countries for a more detailed description of the transitory arrangements of the measures:

- In Slovakia, a recommendation was issued in 2014 for new loans secured by real estate, establishing that the share of new loans granted in a given quarter with a LTV ratio within the range of 90% to 100% should not exceed 25% until 30 June 2015, 20% from 1 July 2015 to 31 March 2016, 15% from 1 April 2016 to 31 December 2016 and 10% from 1 January 2017.[2] In 2017, a mandatory regulation postponing the transition period for the LTV limits was issued. According to this new legal framework, LTV

1. According to the ESRB's publication "Overview of Macroprudential Measures": *https* : *//www.esrb.europa.eu/national*$_p$*olicy/html/index.en.html*, consulted on 10 October 2018.

2. Recommendation No 1/2014 of Národńa Banka Slovenska of 7 October 2014 in the area of macroprudential policy on risks related to market developments in retail lending.

limits above 100% were forbidden. In addition, loans with LTV ratio from 80% to 100% could only represent 50% of the volume of new loans, until 30 June 2017 and 40% as of 1 July of 2017. The phase-in period was defined to prevent a significant impact on the housing loans market.

- Polish banking regulators adopted explicit LTV limits for residential real estate mortgage loans in 2013.[3] A transitional period was allowed along which the limits would be gradually reduced from the initial level of 95% in 2014 to 80% in 2017 (a decrease of 5 p.p. a year).[4] Such phase in regime was foreseen to avoid a reduction on mortgage credit in the early years of the implementation of the regulation.
- In the Netherlands, a LTV cap for residential mortgage loans was introduced in 2012. According to this policy measure, the LTV limit should be reduced from 106% in 2012 to 100% in 2018, at the pace of 1 p.p. a year and it has been announced that further reductions after 2018 are still desirable, but are not yet in place.[5]
- The Czech Republic macroprudential authority issued three recommendations on the provision of retail loans secured by residential property with the aim of mitigating and preventing excessive credit growth and leverage.[6] In 2015, LTV limits for new retail loans were firstly introduced and further tightened one year later.[7] The first recommendation set LTV limits at 100%, with a 10% limit for loans with LTV ratios of 90% to 100%. In 2016, the cap of 100% was decreased to 95%, with a 10% limit for loans with LTV ratios of 85% to 95%, as from 1 October 2016, and to 90%, with a 15% limit for loans with LTV ratios between 80% and 90% as of 1 April 2017.[8]

In the course of 2017, a number of European countries have also undertaken important steps in endowing their national macroprudential policy frameworks with legal powers to adopt borrower-based measures if needed. This was the

3. Two years before, Poland started by applying "soft" LTV limits for mortgage loans, 80% for real estate loans with maturity above five years and 90% for other loans. These measures were considered soft in the sense that banks could apply higher LTV limits as long as they proved the correctness of such an approach.

4. For loans secured by more than 80% with high quality assets, the LTV ratio could reach 90%.

5. Recommendation from the Dutch Financial Stability Committee on the LTV limit after 2018.

6. Czech National Bank recommendations of 16 June 2015, 14 June 2016 and 13 June 2017 on the management of risks associated with the provision of retail loans secured by residential property.

7. The tightening was made through the issuing of another recommendation in face of the risk of a price spiral, given the high rate of growth of new loans and the significant share of new loans with a combination of higher LTV, LTI and DSTI ratios.

8. In addition, it was introduced a maximum LTV limit of 60% for loans to finance buy-to-let residential properties, but it was not subject to a phase in period.

case in Germany, where the Federal Government issued a legal act in which two of those instruments were created, namely the LTV and amortisation requirements.[9] In Austria, the Financial Market Authority, which is the macroprudential authority in this country, will be able to adopt borrower-based measures from July 2018 onwards, such as limits on LTV, DTI and DSTI ratios, as well as limits on maturities of newly granted real estate loans. In Luxembourg a similar legal initiative was taken in 2017, with a draft bill introduced with the purpose of adding borrower-based lending limits in the macroprudential toolkit.

3. Empirical studies on borrower-based measures

There is empirical evidence on the impact of borrower-based macroprudential tools, and in particular of LTV limits. Findings indicate that limits to LTV have a non-negligible impact on house prices and credit. Crowe *et al.* (2011) results based on 21 developed countries suggest that an increase of the maximum LTV limit is associated with a 13% increase in nominal house prices. Using a panel regression with 6 countries, Jacome and Mitra (2015) find that a 10 p.p. decrease of LTV ratios is associated to a reduction of 0.7% of mortgage credit over time. Lim *et al.* (2011) conclude, based on a sample of 49 countries, that the adoption of LTV caps had a negative effect on credit growth and asset price inflation in more than a half of these countries and reduced credit procyclicality. For European countries only, Budnik and Kleibl (2018) use a bivariate analysis that includes borrower-based instruments and conclude that average credit growth declined significantly with the adoption of lending standards restrictions such as LTV or LTI caps. On the contrary, based on a broad dataset covering 119 countries over 2000-2013, Cerutti *et al.* (2017) results do not support a statistically significant effect of borrower-based measures on house prices but show that they are negatively correlated with credit growth.

There are also some single country empirical studies on the macroeconomic impact of macroprudential policy changes. The paper by Neagu *et al.* (2015) looks at the Romanian case and evaluates the effectiveness of the introduction of DSTI and LTV caps, showing that the marginal effect of these measures on credit is around 4.6 p.p. in the first quarter after the implementation and vanishes after two years. The impact on house prices in Romania is not material (given low recourse to bank credit for funding real estate transactions). A related contribution that focus on the impact of regulatory limits on mortgage lending on housing market variables is, for example, Cronin and McQuinn (2016) for the Irish case. Gustafsson *et al.* (2016) do not look at the impact of

9. See Deustch Bundesbank, Financial Stability Review 2017.

macroprudential policy measures but quantify the macroeconomic impact of a decline in housing prices in Sweden.

There are also single country studies of the impact of LTV limits (e.g. Allen *et al.* (2016) for Canadian macroprudential housing finance tools), although they are still scarce for European countries. The study by De Nederlandsche Bank (2015) is one of the few examples where a thorough analysis is conducted, in this case for the Netherlands. The objective of this work is to evaluate the macroeconomic impact of a further tightening of a gradual reduction of the LTV cap to 90%. In this study, a comprehensive set of methodological techniques is employed, including vector autoregression models (VAR), structural VAR and DSGE models, to quantify the benefits and costs associated to a more stringent policy decision. Regarding benefits, the authors find that the positive macroeconomic effects of the measure will be visible mainly in the medium term, supported by a reduced volatility in the housing market and less risky mortgages, which promote more balanced economic growth. In turn, the macroeconomic costs materialise in the transitional period because the majority of first time buyers will have to postpone buying a house, which will decrease the number of housing transactions and house prices. Quantitatively, assuming that the supply of housing is fixed, in the long run the increase of house prices would be 4% to 5% lower than in a scenario in which the LTV would not change. In what regards mortgage debt, projections indicate that mortgage debt will decrease by *circa* 6% in the long term. For the remaining macroeconomic variables, outcomes show that in the long run no significant effects on GDP volume, private consumption, investment and unemployment are reported.

4. Model structure and calibration

4.1. Model structure

We use a structural dynamic general equilibrium model with a rich structure to properly analyse the transmission mechanism of LTV policies. The EAGLE-FLI model, originally developed by Bokan *et al.* (2018), is a large-scale open economy New Keynesian model with financial frictions and a banking sector.[10] In EAGLE-FLI the world is composed of four blocs. Two blocs form a monetary union, the euro area, and are labeled Home and the Rest of the euro area (H and REA, respectively).[11] The other two blocs broadly represent the US and

10. For details on the core structure of the model see Gomes *et al.* (2012) and for details on the enlarged version with financial frictions and a banking sector see Bokan *et al.* (2018).

11. Thus there is a single monetary policy authority for these two blocs and one nominal exchange rate against the other two blocs.

the rest of the world (RW).[12] In what follows we describe the main features of the model, focusing on the Home bloc.[13]

The model includes several types of agents: two types of infinitely lived households, entrepreneurs and banks. There are different types of firms and monetary and fiscal authorities. A crucial feature of our setup is that the two types of households differ in terms of their discount factors. Impatient households discount the future more than patient households, implying that the former are net borrowers while the latter are net lenders *vis-à-vis* the domestic bank (see Iacoviello (2005)). Both types of households gain utility from consumption and from housing services but dislike working. Each household offers a differentiated labour service to domestic firms and act as wage setters under monopolistic competition. Nominal wages are set *à la* Calvo with indexation. Patient households own firms and have access to multiple financial assets, i.e. deposits in the domestic bank, domestic sovereign bonds, US dollar-denominated bonds and in euro area bonds (the last assumption holds only for the two EA blocs). Impatient households only borrow from the domestic banking sector up to a fraction (the LTV ratio) of the pledged collateral, consisting of her housing stock. This simplified setup tries to mimic the widely used framework for mortgage loans.

The entrepreneur maximizes lifetime utility of consumption. The entrepreneur owns the physical capital stock and part of the aggregate domestic stock of real estate, and rents both in a competitive market to domestic intermediate goods firms. The entrepreneur invests in physical capital but adjusting investment levels is costly. Entrepreneurs can also borrow funds from domestic banks and, similarly to the case of impatient households, have to pledge collateral that can be either real estate or physical capital. Therefore, LTV ratios are not only specific to the type of borrowing agents but also to the type of collateral.

There is a representative bank acting under perfect competition that maximizes dividends by choosing the optimal amount of assets and liabilities and taking interest rates as given. The bank finances loans by collecting deposits from domestic patient households and raising capital. There is also an interbank market for loans between the two euro area blocs. Similarly to Kollmann (2013), the bank faces a regulatory capital requirement. Deviating from the long run level of the capital requirement implies a cost. Even though this requirement is exogenously imposed, it may be rationalized, since bank capital requirements can limit moral hazard in the presence of informational frictions and deposit insurance.

12. Having two blocs outside the euro area allows for a detailed calibration of the trade links of the euro area countries but this feature is not explored in our simulations.

13. The other blocs have a similar structure. The main exception is that in the euro area we assume the existence of a cross-border interbank market.

There are two types of firms: one produces intermediate goods (that can be either internationally tradable or nontradable) and the other produces nontradable final goods for consumption and investment purposes (there is also a non-tradable final public good). The final nontradable goods producing firm acts under perfect competition. The inputs for production are nontradable and domestic and imported tradable intermediate goods. The intermediate goods producing firms use a constant elasticity of substitution technology and sell their differentiated output under monopolistic competition. The tradable intermediate good firm discriminates prices across countries by setting the price of its brand in the currency of the destination market. Prices adjust sluggishly due to staggered price contracts *à la* Calvo with indexation.

The monetary authorities set the policy rate according to Taylor-type rules that react to year-on-year inflation and quarterly real output growth. In the euro area, there is a single monetary authority that reacts to euro area wide variables, i.e. a weighted (by regional size) average of inflation and output growth in the two blocs. The fiscal authority purchases a final good which is a composite of nontradable intermediate goods only, makes transfer payments to households, issues short term bonds to refinance its debt and levies both *lump-sum*[14] and distortionary taxes (tax rates are exogenously set and kept fixed in our simulations).

4.2. Model calibration

The model is calibrated at the quarterly frequency. The two euro area blocs are calibrated to represent Portugal (Home) and the REA. We set parameter values to match great ratios and banking variables (as a ratio to GDP) or we set them in line with the literature. The calibration is summarised in Tables 1 to 7. We start by discussing the calibration of the LTV ratios that are of crucial importance to our analysis and then briefly comment on the remaining parameters.

LTV ratios. The calibration of the LTV ratios for different type of borrowers is summarised in Table 1. Impatient households' LTV ratio is set to 70% in both euro area regions, in line with Lombardo and McAdam (2012). Entrepreneurs' LTV ratio associated with housing is also set to 70%, while the one associated with capital is set to 30%, in line with the literature (Gambacorta and Signoretti (2014)). Regarding Portugal, a LTV ratio of 70% corresponds to the average ratio over 2014-2015 (measured as the ratio of new loans over the house appraisal, see Banco de Portugal, 2017).

One note of caution is needed. Some features of the model might interfere with the interpretation of LTV limits and their equivalence into actual policy limits. In particular, in the model agents are homogeneous with respect to the

14. These taxes are used to stabilize public debt.

level of debt and the LTV limit (in this case by type of agent), while in fact individual loan contracts exhibit a distribution of LTV levels quite disperse from the mean.[15] The distributional effects of these policy measures are an important issue that is however beyond the scope of the current analysis.[16] Also, in the model all loans are one-period loans, so the borrowing constraint imposed on new loans has a similar impact on the stock of loans. Given the typical long average maturity of mortgages, the imposition of LTV limits actually affects only modestly the LTV of the stock of loans which is normally much lower than that of new loans.[17] This, however, does not affect significantly the results of the model, as most of the effects of the LTV shock are transmitted through the credit channel and housing market, which are affected only by new loans. The model is likely to overestimate banks' balance sheet adjustments needed to accommodate the changes in credit as these are affected by the stock of credit.

Other parameters. The calibration of the remaining parameters is in line with the data when possible and with the values used in the literature. We set the share of patient households in each region to 30%, the share of impatient households to 50%, the share of entrepreneurs to 10% and the share of bankers to 10%. We follow Bokan *et al.* (2018) in the calibration of real rigidities and adjustment costs.

Table 2 reports banks' balance sheet components and parameters related to the banking sector. The sources of the data used are Eurostat Annual Sector Accounts and the Federal Reserve Board Financial Accounts (and refer to nominal outstanding amounts at the end of the year divided by annual nominal GDP). Given the lack of available data on collateralized loans for purposes other than housing, we choose to match the average share (1999-2013 period) of total loans to households. Given the matched values for loans to households, the assumed zero interbank position and zero excess bank capital in the steady state, the calibration of the capital requirement and the entrepreneurs' LTV ratios, we allow deposits to endogenously adjust consistently with the bank's balance sheet. This calibration strategy emphasizes the role of bank's loans and thus induces a broad interpretation of deposits (given the absence of other financing sources in the model). The capital requirement parameter is set to 8% in all blocs, consistent with the BASEL III minimum requirement for total capital.

15. For example, in the model the imposition of a LTV limit higher than 70% would imply a relaxation of credit conditions with an expansionary effect on the economy. However, looking at the sample of existing Portuguese loan contracts, imposing a LTV limit as high as 90% or even higher could have a tightening effect on some credit because the distribution of loans has a relative fat tail.

16. For an empirical analysis of the distributional effects of regulation understood in a more general sense (related to labour, business and credit) see Adams and Atsu (2015).

17. For example, for Portugal, in 2015 the average LTV on new credit flows at the origin averaged 71.2%, while that on the stock of credit was 59.8%.

Table 3 reports the matched great ratios. National accounts data for the EA regions and the US are from Eurostat. Region sizes match the share of world GDP based on IMF data. The data sources for net foreign asset position data are Eurostat and Bureau of Economic Analysis.

Table 4 reports population shares, preference and technology parameters. Preferences are assumed to be the same across household types and regions and the calibration mostly follows Bokan *et al.* (2018). The discount factor of patient households implies a steady-state annualized real interest rate of about 3%. The discount factor of impatient households are set to a lower level while the one for entrepreneurs to a higher one. The discount factor for banks is assumed the same as for patient households.

The Cobb-Douglas production functions bias towards capital is set to around 0.30 and the bias towards housing to 0.01 in the tradable and nontradable intermediate goods sector. As for the final goods baskets, the degree of substitutability between domestic and imported tradables is higher than that between tradables and nontradables, consistent with existing literature. Markups in the EA nontradables sector (a proxy for the services sector) and labor market are higher than the corresponding values in the US and RW and the markup in the tradables sector (a proxy for the manufacturing sector) is the same in all blocs. The markup in the nontradables sector is higher than that in the labour market.

Table 5 reports nominal and real rigidities. We set Calvo price parameters in the domestic tradables and nontradables sector to 0.92 (12.5 quarters) in the EA, consistently with estimates by Warne *et al.* (2008) and Smets and Wouters (2004). Corresponding nominal rigidities outside the EA are equal to 0.75, implying an average frequency of adjustment equal to 4 quarters, in line with Faruqee *et al.* (2007). Calvo wage and price parameters in the export sector are equal to 0.75 in all the regions. The indexation parameters on prices and wages are calibrated so to get sufficiently hump-shaped response of wages and prices.

We set weights of bilateral imports on the consumption and investment bundles to match the trade matrix reported in Table 6 (based on Eurostat and IMF trade statistics). The Portuguese economy is a relatively open economy and its main trading partner is the REA. On the contrary, the REA is not as open and is trading to a great extent with the RW bloc.

Table 7 reports monetary policy and fiscal rules parameters. The interest rate rule reacts to inflation and quarterly output growth and includes inertia. Steady state government debt to output ratios equal to 60% in annual terms and tax rates are consistent with empirical evidence (see Coenen *et al.* (2008)).

5. Simulations

In this section, we explore the macroeconomic impact of limits to LTV ratios.[18] The reasons to choose this as a macroprudential instrument are twofold. First, the application of caps to LTV ratios is part of the macroprudential toolkit of several European authorities and have already been extensively used worldwide. Second, experience shows that systemic risk can be related to exuberant housing markets and the introduction of upper limits to LTV ratios may help curbing the private sector leverage (Jacome and Mitra (2015)). Having this in mind, we investigate the impact of a 5 p.p. tightening of the LTV ratio under different policy designs.[19] We consider two policy approaches based on the cross-country experience with these borrower-based measures: (i) a full and immediate introduction of the permanent LTV limit (as occurred in Ireland and Portugal, for example); (ii) a gradual introduction of the LTV limit, i.e. the regulator sets a phase-in period in which the pace of adjustment is defined (e.g. as in the Polish or the Dutch cases). For the sake of comparison, we also show the results of a similar transitory but persistent reduction of the LTV limit. From the viewpoint of policymakers, the imposition of both temporary and permanent changes in the LTV ratios can be justified with different policy goals. A temporary tightening of collateral constraints may be more appropriate when the objective of the policymaker is to affect the financial cycle (e.g. mitigate the excessive expansion of credit) while the regulators concerned with structural vulnerabilities would favour a permanent change in LTV limits.

Finally, we also discuss the results of a similar LTV reduction in the euro area as a whole, i.e. a simultaneous reduction in the two euro area blocs. This scenario could resemble a situation in which the changes are introduced at the same time by national authorities (either coincidentally or coordinately) or in which a supranational authority, e.g. the European Central Bank (ECB), could set similar measures and apply them to the euro area as a whole.[20]

5.1. The case of a small euro area country

The LTV limit is reduced permanently by 5 p.p. in the Portuguese bloc either immediately (instantaneous shock) or gradually over a period of roughly 10 years (the LTV ratio follows an AR(1) process with autocorrelation coefficient equal to 0.9). We compare these scenarios with a temporary shock, where the

18. We assume this tool is under the full control of the policymaker.

19. We assume that the national regulator acts independently from the other regulators, i.e. both macroprudential regulators in other countries and the monetary authority.

20. As established in the SSM Regulation, the ECB has top up macroprudential powers regarding the deployment of macroprudential instruments (Regulation (EU) No 575/2013 and Directive 2013/36/EU). Borrower-based measures are not currently foreseen in those regulatory packages, so the ECB cannot currently use its top up powers on them.

LTV ratio is assumed to decrease by 5 p.p. on impact and then to gradually return to its initial level over a period of 10 years (according to an AR(1) process with autocorrelation coefficient equal to 0.9). Figure 1 shows the three LTV trajectories considered.

Table 8 summarizes the long-run impact of the permanent policy measure. The reduction of the LTV leads to a long-run decrease of bank lending to the private sector. In particular, impatient households borrowing drops considerably, as these are the agents that face a tightening in their borrowing limit. The lower demand for loans reduces the demand for collateral and, as a result, in the new steady state impatient households hold less housing at lower house prices. These results are in line with the objectives the policy authorities have put forward when implementing such policies. The decline in the value of collateral also has an (endogenous) impact on the borrowing capacity of the other type of indebted agents, i.e. entrepreneurs, but they increase their holdings of housing, as it is cheaper in the new steady state, so borrowing by entrepreneurs declines only marginally.

One salient feature is that the long-run macroeconomic impact in terms of GDP and its main components is small. This is in part related to the fact that the policy measure affects the borrowing limit of only part of the population but also due to some offsetting impact across different types of agents. In particular, consumption of patient households falls slightly (they hold more houses that are worth less) but consumption of impatient households actually increases because the policy measure leads them to restructure their balance sheets away from buying houses (and borrowing). On the banking side, the decrease in loans is matched by a decrease in deposits, given that we assume that in the new steady state banks continue to comply with the capital requirement at the minimum level and thus let deposits to adjust accordingly. The spillovers to the other euro area economy are negligible, given that the measure is implemented in a small fraction of households of a small economy within the euro area.

Figures 2 to 3 show the transition to the new steady state. Results for the two cases are qualitatively similar but there is a noticeably deeper tightening of financial variables in the short run if the policy change is immediately implemented. Interestingly, even in the phased-in shock, where the initial adjustment of the LTV ratio is small (in this case after one year the LTV ratio is still only 1 p.p. down from the initial level), agents anticipate future reductions and as such front load the adjustment. Overall, a permanent reduction in the LTV ratio tightens the collateral constraint of borrowers, corresponding to a shift in the demand schedule for loans. As such, the exogenous reduction of the LTV ratio implies lower borrowing by impatient households and consequently lower need for collateral. The lower demand for housing contributes to decrease house prices, further constraining the access to credit, as the value of the collateral decreases. Lower house prices also contribute to initially constrain the borrowing capacity of entrepreneurs, even though the LTV limit did not apply directly to them. This effect is latter partially reversed as house

prices converge to their steady state and due to some crowding-in effect of lower household borrowing. Lower demand for credit reduces interest rates on loans and, thereby, on deposits. Patient households reduce their deposits and consumption and increase housing purchases due to lower prices. The macroprudential policy feeds through to the real economy, with a contraction of consumption, investment and GDP. The monetary policy rate is virtually unchanged as the effects of a change in the Portuguese LTV ratio on euro area inflation and output growth are very small.

A temporary LTV change shows important differences. The recessionary impact is smaller in the temporary case, where agents anticipate that the more restrictive borrowing constraint is going to be alleviated in the medium run and the LTV ratio will return to the initial level. Also, beyond the shorter run the dynamics of the permanent and transitory case are, as expected, significantly different, given that, in the permanent policy, both the LTV ratio and the economy as a whole converge to a new equilibrium.

5.2. The euro area case

In this section we analyse the results of a change in the LTV ratio for the euro area as a whole. We compare the impact of a permanent euro area shock with the previous section results of a shock in Portugal. As before, the shock consists of an exogenous permanent phased-in tightening of the collateral constraint of impatient borrowers from 70% to 65%.

Table 8 shows the long-run impact and Figure 4 illustrates the adjustment dynamics for the Portuguese economy in the two scenarios considered. The impact of the LTV shock in the euro area as a whole has two main differences compared to that of the Portuguese case. First, there is a generally stronger macroeconomic impact in the Portuguese economy in the long-run, namely due to the negative spillovers from the REA. Second, the impact in the short term is partly offset by the monetary policy response in the short run. This effect contributes to reduce the interest rates on loans and deposits even further, and thereby minimises the short term LTV impact on loans by impatient households and on house prices - the mitigating effect on loans is smaller, given the LTV constraint, and not immediate, as the policy rate also reacts with a lag. As the impact of the monetary policy reaction wears out, the negative spillovers from the contraction of the REA economy dominate, which contributes to magnify the effects of the LTV shock on financial variables and on the real economy.

6. Policy implications and concluding remarks

We analysed the macroeconomic impact of permanent and transitory changes to the LTV ratio in a large scale structural general equilibrium model of the euro area. Our main results show that in the long run a (permanent) policy

change in a small euro area economy leads to lower borrowing, lower deposits, lower house prices and a mild contractionary effect on economic activity. In the short run this measure has a greater tightening impact on credit conditions. Importantly, the magnitude of the short-run contraction depends on the policy design, being more pronounced the more rapid and long-lasting is the policy change. A similar reduction of LTV ratio in the euro area as a whole leads to a somewhat greater euro area output contraction in the euro area and the small economy in the long-run but in the short run monetary policy partially offsets the contractionary impact. We also compare the results of a permanent LTV change with those of a temporary, but persistent one. The milder recessionary effects in lending and in the real economy from a temporary tightening of the LTV cap are mainly determined by the agents anticipation of the medium run ease of the borrowing constraint. Results show that temporary LTV shocks seem to be more adequate to curb cyclical risks than structural ones, even when those shocks are calibrated to be highly persistent.

Our results have important policy implications. The model illustrates the macroeconomic impact of LTV policy measures and importantly the mechanisms underlying the usually used argument that LTV-policies are a way to contain credit and house prices. Crucially, we also show that a phase-in period of implementation of the policy measures implies a milder contraction in the shorter-run. This is important as the recessionary impact of reforms frequently generated opposition to its implementation, in particular from the subset of the population directly influenced by the measure. This may result in obstacles to implementation that could lead to an unwinding of measures. Also, our findings show that the different implementation choices of macroprudential measures used worldwide have non-negligible implications in terms of the behaviour of the economies. The models results support the announced policy objectives of gradually introducing permanent LTV ratios, which are usually associated to the policymakers concern of not causing disruptive impacts on the flow of credit to the economy in the early periods after the adoption of the measure.

Moreover, the use of a fully structural model also allows us to think of another policy relevant question: the interaction between different macroeconomic policies. In particular, the model not only assumes independent macroprudential and monetary policies but also that monetary policy does not react to financial variables. Still, its general equilibrium nature implies that the action of one policy implies a reaction of the other. Results show that the introduction of LTV limits in a small euro area country does not lead to a monetary policy response, because the effects on the euro area output and inflation rate are relatively small. However, the introduction of a euro area wide measure leads to a response of monetary policy that partially mitigates the tightening effect of the LTV policies in the short-run. Even though at first this could be seen as a tension between policies, one should remember that the full impact of the macroprudential policy is seen in the long-run and, as explained

above, the monetary policy action may actually be helpful as it may make it more likely that the macroprudential measure is successfully implemented.

Several extensions of the model would be of interest, namely introducing different maturity loans, heterogeneity among agents regarding the distribution of LTV ratios and the possibility for the borrowing constraints to bind only occasionally. We leave these issues for future research.

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	Home	REA	US	RW
Households	0.7	0.7	0.7	0.7
Entrepreneurs - housing stock	0.7	0.7	0.7	0.7
Entrepreneurs - capital stock	0.3	0.3	0.3	0.3

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 1. LTV ratios

	Home	REA	US	RW
Loans	136	132	160	145
Loans to households	61	64	90	76
Loans to entrepreneurs	75	68	70	70
Interbank	0.0	0.0	n.a.	n.a.
Deposits	125	121	148	134
Excess bank capital	0.0	0.0	0.0	0.0
Hous. and entr. loans smoothing	0.4	0.4	0.4	0.4
Capital requirement	0.08	0.08	0.08	0.08
Banks discount factor	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$
Banks share in the population	0.10	0.10	0.10	0.10

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 2. Steady-State Financial Accounts (Ratio to annual GDP, %) and banking sector parameters

	Home	REA	US	RW
Domestic demand				
Private consumption	55	59	63	62
Private investment	23	20	21	21
Public consumption	20	21	15	18
Trade				
Imports (total)	38	20	15	12
Imports of consumption goods	24	12	8	5
Imports of investment goods	15	9	7	6
Net foreign assets (ratio to annual GDP)	-82	-8	-18	13
Production				
Tradables	60	45	45	42
Nontradables	40	55	55	58
Labour	39	38	46	45
Share of World GDP	0.3	20.9	20.6	58.2

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 3. Steady-State National Accounts (Ratio to GDP, %)

	Home	REA	US	RW
Households and entrepreneurs				
Patient hous. discount factor	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$
Imp. households discount factor	0.96	0.96	0.96	0.96
Entrepreneurs discount factor	0.99	0.99	0.99	0.99
Intertemporal elasticity of substitution	1.00	1.00	1.00	1.00
Inverse of the Frisch elasticity of labor	2.00	2.00	2.00	2.00
Housing services	0.10	0.10	0.10	0.10
Habit persistence	0.70	0.70	0.70	0.70
Capital depreciation rate	0.025	0.025	0.025	0.025
Housing depreciation rate	0.01	0.01	0.01	0.01
Wage markup	1.30	1.30	1.16	1.16
Intermediate-good firms (trad. and nontrad. sectors)				
Substitution btw. labor and capital	1.00	1.00	1.00	1.00
Bias towards capital - tradables	0.30	0.30	0.30	0.30
Bias towards housing - tradables	0.01	0.01	0.01	0.01
Bias towards capital - nontradables	0.68	0.51	0.45	0.43
Bias towards housing - nontradables	0.01	0.01	0.01	0.01
Substitution btw. I-type and J-type labor	4.33	4.33	7.25	7.25
Price markup - Tradables	1.20	1.20	1.20	1.20
Price markup - Non-Tradables	1.50	1.50	1.28	1.28

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 4. Households, Entrepreneurs and Firms Behavior

	Home	REA	US	RW
Calvo parameters				
Wages (I and J)	0.75	0.75	0.75	0.75
Prices - domestic tradables	0.92	0.92	0.75	0.75
Prices - exports	0.75	0.75	0.75	0.75
Degree of indexation				
Wages (I and J)	0.75	0.75	0.75	0.75
Prices - domestic tradables	0.50	0.50	0.50	0.50
Prices - exports	0.50	0.50	0.50	0.50

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 5. Real and Nominal Rigidities

	Home	REA	US	RW
Consumption-good imports				
Substitution btw. consumption good imports	2.50	2.50	2.50	2.50
Total consumption good imports	23.6	11.5	8.3	5.3
From partner				
Home	-	0.3	0.01	0.05
REA	15.6	-	1.1	3.2
US	0.3	0.9	-	2.1
RW	7.7	10.4	7.2	-
Investment-good imports				
Substitution btw. investment good imports	2.50	2.50	2.50	2.50
Total investment good imports	14.7	9.0	6.9	6.2
From partner				
Home	-	0.1	0.1	0.03
REA	9.2	-	1.0	3.4
US	0.5	1.3	-	2.8
RW	5.0	7.5	7.5	-

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 6. International Linkages (Trade Matrix, Share of Domestic GDP, %)

	Home	REA	US	RW
Monetary authority				
Inflation target	1.02	1.02	1.02	1.02
Inertia	0.87	0.87	0.87	0.87
Response to inflation gap	1.70	1.70	1.70	1.70
Response to output growth	0.10	0.10	0.10	0.10
Fiscal authority				
Government debt-to-output ratio	2.40	2.40	2.40	2.40
Sensitivity of lump-sum taxes to debt/output	5.00	5.00	5.00	5.00
Consumption tax rate	0.185	0.192	0.078	0.123
Capital income tax rate	0.19	0.19	0.16	0.16
Labour income tax rate	0.079	0.151	0.154	0.100
Rate of social security contribution by firms	0.092	0.150	0.078	0.109
Rate of social security contribution by households	0.063	0.077	0.067	0.079

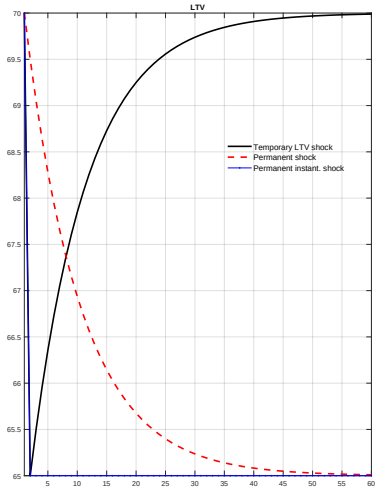
Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

TABLE 7. Monetary and Fiscal Policy

	EAA LTV change	EA LTV change	
	Home	Home	REA
LTV (in p.p.)	-5	-5	-5
Loans	-4.73	-4.85	-5.18
Loans to impat. hous.	-9.94	-10.05	-10.07
Loans to entrepreneurs	-0.5	-0.62	-0.55
Deposits	-4.73	-4.85	-5.18
House Prices	-1.95	-2.07	-2.07
Real GDP	-0.59	-0.65	-0.59
Consumption	-0.50	-0.62	-0.55
Consumption - patient hous.	-0.9	-1.02	-1.00
Consumption - impat. hous.	2.63	2.50	2.47
Investment	-0.48	-0.61	-0.52
Housing - patient hous.	1.07	1.07	1.09
Housing - impat. hous.	-1.08	-1.08	-1.11
Housing - entrepreneurs	1.48	1.48	1.54

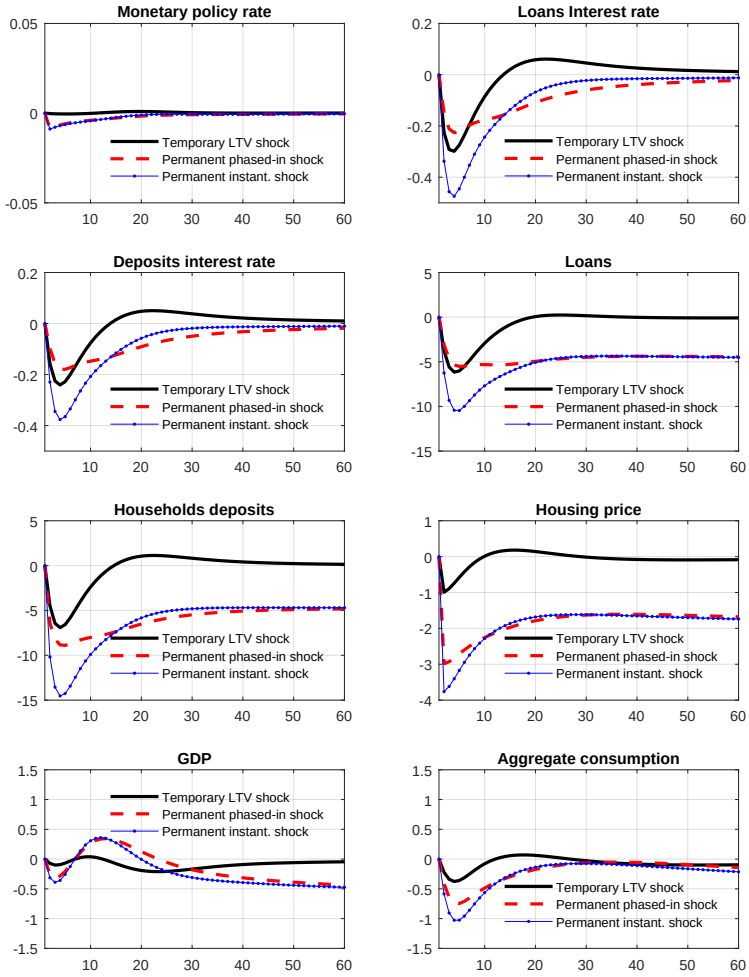
Note: REA=Rest of Euro Area

TABLE 8. Change in the LTV ratio - steady state impact (% except for LTV)



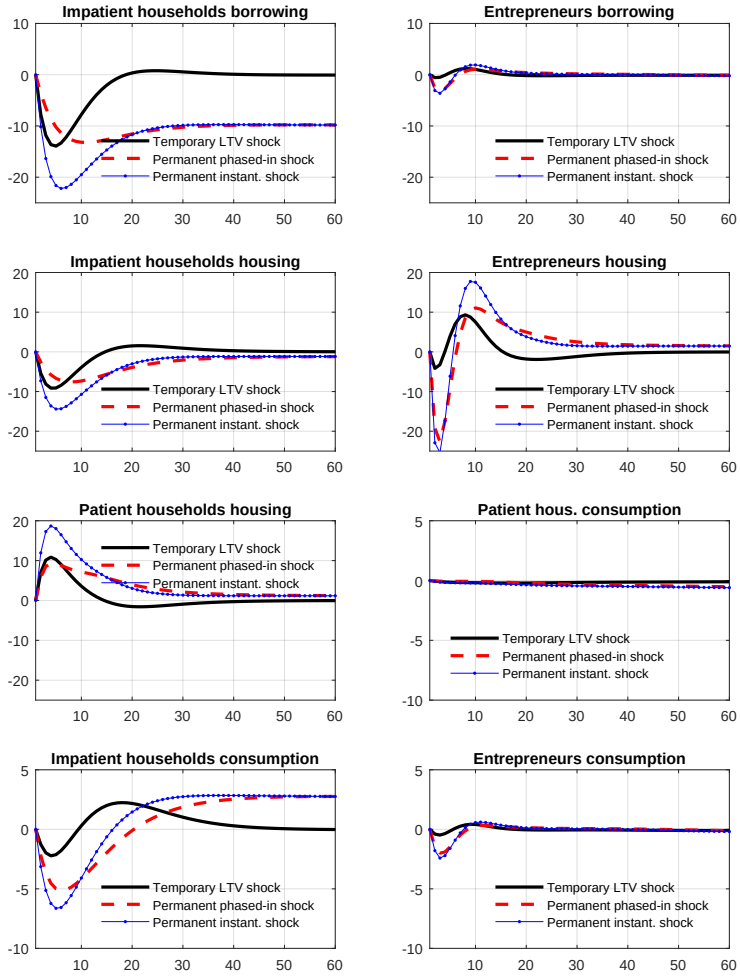
Notes: Horizontal axis: quarters. Vertical axis: %.

FIGURE 1: LTV shocks in a small open economy of the euro area



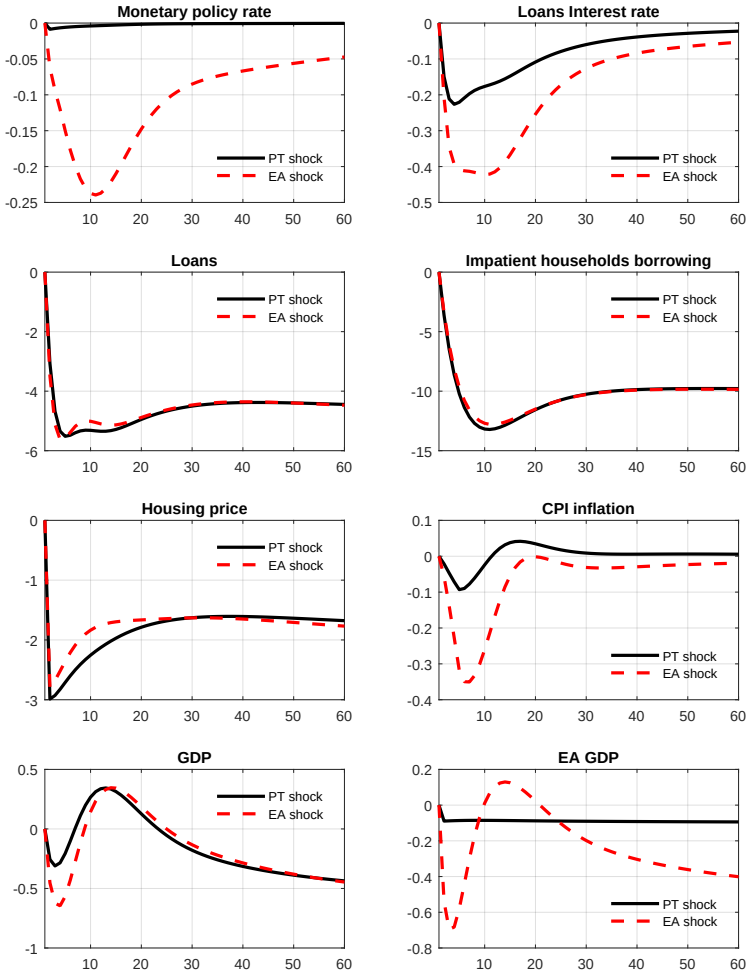
Notes: Horizontal axis: quarters. Vertical axis: % deviations from the baseline except for interest rates that are expressed in p.p.

FIGURE 2: Impact of changing LTV ratios in a small region of the euro area - effects in the small region



Notes: Horizontal axis: quarters. Vertical axis: % deviations from the baseline except for inflation that is expressed in p.p.

FIGURE 3: Impact of changing LTV ratios in a small region of the euro area - effects in the small region (cont.)



Notes: Horizontal axis: quarters. Vertical axis: % deviations from the baseline except for interest rates and inflation that are expressed in p.p.

FIGURE 4: Impact of changing LTV ratios in the euro area - effects in the small region

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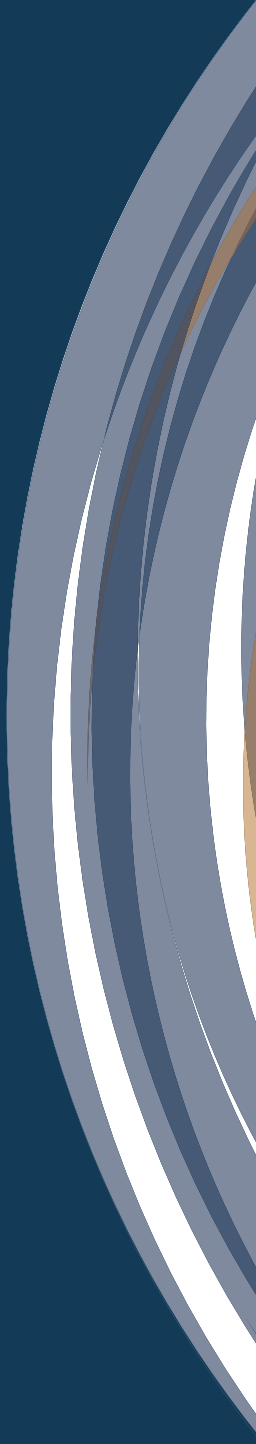

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